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AUTHOR(S): George Marklin

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EQUILIBRIUM OF THE KINK SOURCE EXPERIMENT*

George Marklin
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

The kink source experiment^{1,2,3} (KSX) was conceived of as a method of injecting helicity into a spheromak making special use of the $m=1$ helical Taylor state. It has a Z pinch as a helicity generating source, connected to a flux conserver through an entrance region (see Fig. 1). Since the entrance region is a long (length > diameter) cylinder, the magnetic field should be close to the helical Taylor state, which is the minimum energy configuration of a magnetized plasma in an infinite cylinder with no net flux. This paper will be concerned with modeling the actual fields in the entrance region of the KSX using zero-beta ideal MHD equilibrium theory.

Figure 1 is a diagram of the KSX showing the location of the main diagnostic; the surface magnetic probe array in the midplane of the entrance region. These probes measure B_θ and B_z at the wall at 7 different angles, giving 14 data points to which the theoretical models will be fit.

To simplify the equilibrium computations, the entrance region will be modeled as an infinite cylinder with helical symmetry and all physical quantities will be assumed to depend only on the radius and the helical angle $\varphi = \theta - kz$. Neglecting the pressure, the magnetic field satisfies the force-free equation

$$\underline{j} = \lambda(\psi)\underline{B} \quad , \quad (1)$$

where $\lambda(\psi)$ is an arbitrary function of the helical flux $\psi = A_z + krA_\theta$, a gauge invariant function of the vector potential \underline{A} . The λ profile will be modeled as a linear function of the normalized flux $x = (\psi - \psi_{\min})/(\psi_{\max} - \psi_{\min})$:

$$\lambda(\psi) = \bar{\lambda} [1 + \alpha(2x-1)] \quad , \quad (2)$$

with an adjustable parameter α to control the slope. The range of α goes from 0. (the Taylor state) to 1, where the current is peaked at the positive magnetic

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axis $x=1$, and goes to zero at the negative magnetic axis $x=0$, giving a net current flowing through the entrance region. The parameter $\bar{\lambda}$, the average of $\lambda(\psi)$ over ψ , is an eigenvalue which is inversely proportional to the radius of the entrance region and weakly dependent on k and α .

Equation 1 is solved numerically by introducing a vector potential in the Coulomb gauge and integrating the time dependent equation

$$-\nabla^2 \underline{\dot{A}} = (\lambda/\bar{\lambda}) \nabla \times \underline{A} \quad , \quad (3)$$

to find the fastest exponentially growing mode. The eigenvalue $\bar{\lambda}$ is then the inverse of the growth rate. The time advance is fully implicit with the time step chosen to give the fastest convergence (typically $\Delta t \sim 3$). The boundary conditions are $A_\theta = A_z = 0$ and $\partial/\partial r (rA_r) = 0$ at the wall, and the appropriate symmetry conditions at $r=0$. The surface magnetic fields are thus computed as functions of k and α . These solutions are fit to the data by minimizing a mean square error function;

$$E(B_0, \vartheta_0, k, \alpha) = \sum_{i=1}^7 [B_0 B_\vartheta^C(\vartheta_i - \vartheta_0) - B_\vartheta^M(\vartheta_i)]^2 + [B_0 B_z^C(\vartheta_i - \vartheta_0) - B_z^M(\vartheta_i)]^2 \quad , \quad (4)$$

with respect to the amplitude B_0 , the phase ϑ_0 , and k and α . Here B^C and B^M are the computed and measured fields respectively.

Figure 2 shows the best fits obtained at three different times during a typical KSX shot. The magnetic fields at the surface are plotted on the left as a function of ϑ , along with the experimental data points. The contours of the helical flux, which are the magnetic surfaces, are plotted on the right. These contour plots are in the midplane of the entrance region looking in from the flux conserver. The electrode is behind and to the left. Figure 2a is at $t = 100 \mu s$ with $k=1$, $\alpha = 0.5$ and $\vartheta_0 = -22^\circ$. There is a net current flowing through the entrance region with only 33% of the electrode current returning through the plasma. (The rest returns through the wall.) Figure 2b is at $t = 150 \mu s$ with $k = 1.5$, $\alpha = 0.45$ and $\vartheta_0 = +4^\circ$. The return current here is 42%. Figure 2c is at $t = 200 \mu s$ with $k = 1.6$, $\alpha = 0.3$ and $\vartheta_0 = -14^\circ$, and the return current here is 67%.

There seems to be evidence of a general trend that as the electrode current decays away α decreases, which means that the positive and negative currents in the entrance region are more nearly balanced; and k seems to increase, possibly indicating that the plasma is being axially compressed back toward the source.

References

1. T. R. Jarboe, C. W. Barnes, D. A. Platts, and B. L. Wright. "Comments on Plasma Physics and Controlled Fusion," Vol. IX, No. 4 (1985).
2. D. A. Platts, T. R. Jarboe, and B. L. Wright, this proceeding.
3. B. L. Wright, T. R. Jarboe, and D. A. Platts, this proceeding.

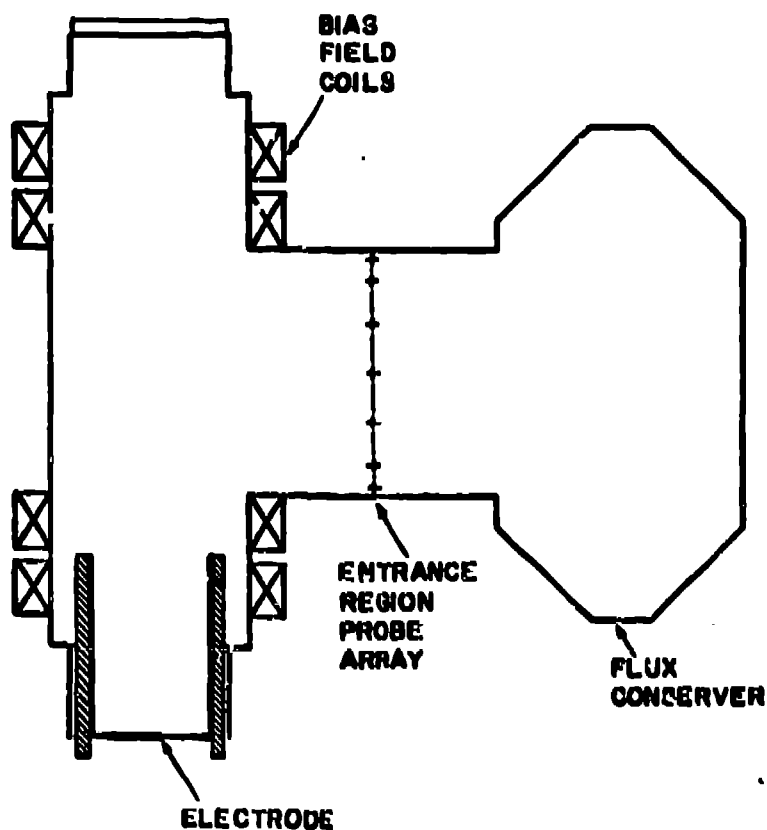


Fig. 1. Diagram of the kink source experiment.

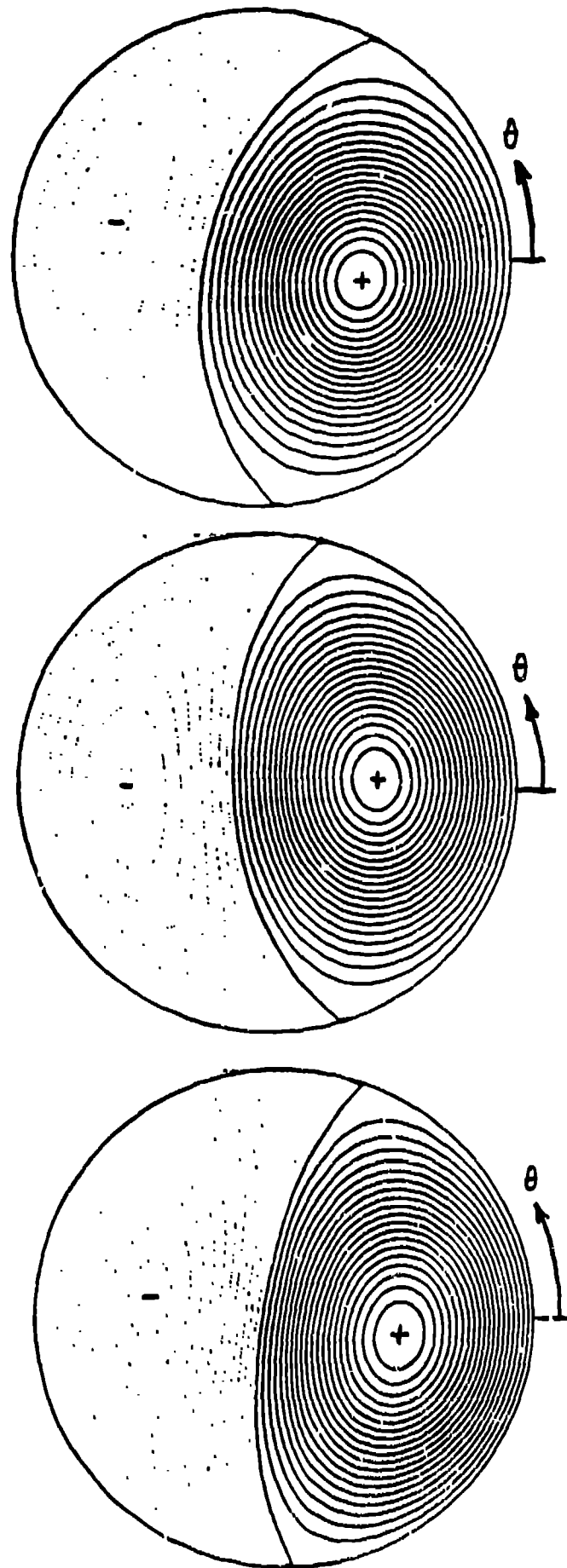
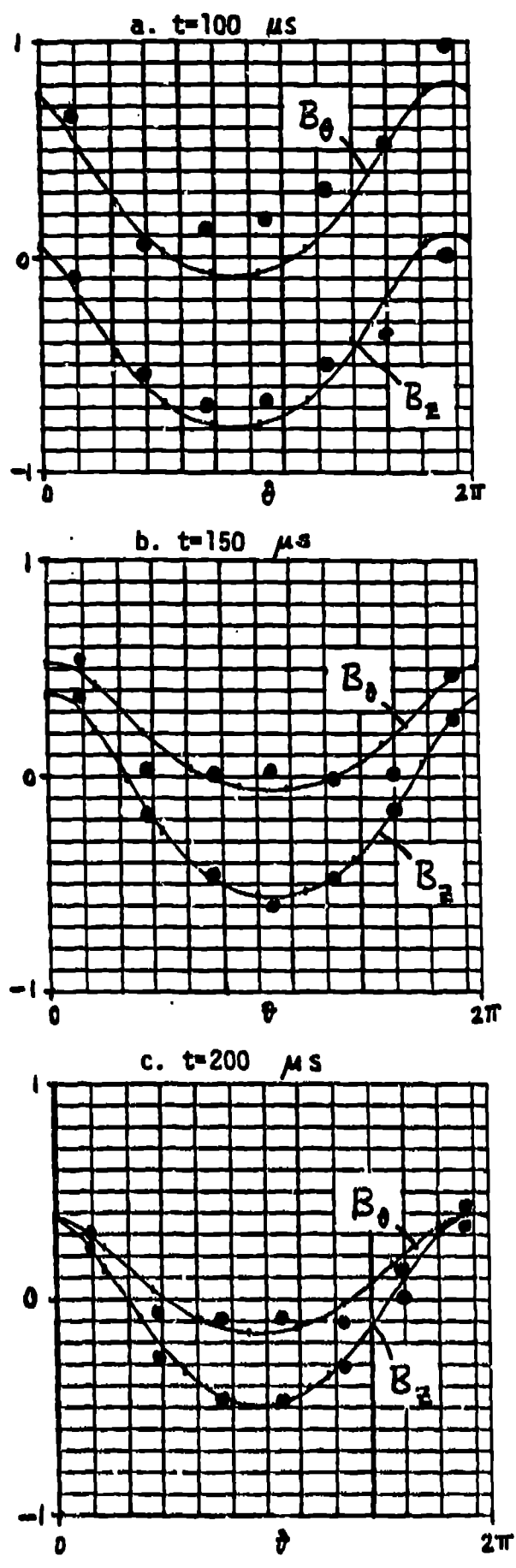


Fig. 2. Surface magnetic fields and helical flux contours.